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www.upc.es/aie

BREEAM BRE Environmental Assessment Method

www.breeam.org

BUILDING ENERGY MEASUREMENT AND PERFORMANCE ANALYSIS

<http://eetd.lbl.gov/EA/Buildings/PROJECTS/>

CIBSE: THE CHARTERED INSTITUTION OF BUILDING SERVICES ENGINEERS

www.cibse.org

CODIGO TÉCNICO DE LA EDIFICACIÓN

www.codigotecnico.org

CSTB: CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT

www.cstb.fr

EEA - EUROPEAN ENVIRONMENT AGENCY

www.eea.eu.int

ENERGIE-CITÉS; ASOCIACIÓN DE MUNICIPIOS EUROPEOS PARA EL DESARROLLO DE LA ENERGÍA EN EL MEDIO URBANO

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http://europa.eu.int/comm/dgs/energy_transport/index_es.html

ICAEN: INSTITUT CATALÁ D' ENERGIA

www.icaen.net

IDAE: INSTITUTO PARA LA DIVERSIFICACIÓN Y AHORRO DE LA ENERGÍA

www.idae.es

IBPSA: INTERNATIONAL BUILDING PERFORMANCE SIMULATION ASSOCIATION

www.ibpsa.org

NREL: THE NATIONAL RENEWABLE ENERGY LABORATORY

www.nrel.gov

UNIVERSIDAD DE LAS PLAMAS DE GRAN CANARIA. Escuela de arquitectura. Departamento de construcción

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8. Ponencias presentadas y artículos publicados

Ponencias presentadas

- Ponencia leída en el **8th World Renewable Energy Congress August 28 - September 3, 2004 in Denver, Colorado**. En el apartado Low Energy Architecture.

Energy consumption indicators for Technical University of Catalonia (UPC) buildings

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Abstract.

The aim of this paper is to show an experience in the definition of indicators to measure the influence of the buildings use in the energy consumption, against the other factors that influence it.

This paper summarizes the study carried out by the authors by assignment of the Environmental Plan of Technical University of Catalonia (UPC) on the possibility of assessing the associated consumption to the different uses (educational, research, management, library, etc.) typified and quantified for the university spaces. The interest of the study for the UPC is to explore the possibility of determining possible energy efficiency policies based on actions on the user, that did not suppose discrimination in function of the different infrastructure that are used or the different types of activity that are carried out.

To do so it, was necessary to separate the different factors that influence in the energy consumption and, above all, to measure simultaneously the consumption and the use in each monitored building.

Particularly, the work consisted in collecting information of the energy consumption and the intensity of use in the annual academic cycle in 6 buildings of the Technical University. The buildings were selected in accordance with the characteristics of architecture, use and location. They were splitted into two groups, one with 3 buildings with common characteristics of architecture and location, but with different uses, and the other with similar uses but with differences in architectural characteristics and location.

The results of the study permit to carry out some discussion on which are the adequate indicators, to measure the energy consumption in relation to the use of the buildings, but also to establish the relation between the use of the buildings and their energy consumption.

- Ponencia leída en el **3rd Dubrovnik Conference On Sustainable Development of; ENERGY, WATER AND ENVIRONMENT SYSTEM, June 2005 in Dubrovnik, Croacia**. En la sesión: Environmental Assessment.

About the environmental impact of buildings:
Analysis of the incidence of the use of the buildings in the
energy consumption

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Abstract.

The consideration of the use of the buildings as one of the factors of greater incidence in the final energy consumption in the buildings is the initial approach of this work that proposes a methodology that permit to quantify, to value and to analyze this influence. Understanding that the use is not only referred to the activities that develop in a building but also to the energy resources that utilizes to carry out these activities and to satisfy the needs of comfort of the users, the total consumption of energy will be related to the different energy uses in the building. Taking as premise that for each energy use the consumption should be related to the systems and available machines in the building, its performance and the use that be done of them. If we consider each one of these factors as a variable to know, the energy consumption (theoretical) would be able to be defined according to the solution of the following equation in which there would be to establish the interaction of the different variables:

$$EC = P * R * U$$

Where:

EC = Energy consumption
P = Power installed
R = Performance/efficiency of systems
U = Use

The study and the resolution of this equation suppose the initial approach to verify by means of the analysis of some buildings of the UPC in the development of a doctoral thesis and in the framework of different research projects promoted from Environmental Plan Office.

- **Artículos publicados:**

Como resultado del trabajo realizado en los 6 edificios de la UPC analizados en detalle en esta tesis y cuyos resultados se presentaron en los informes de los proyectos de investigación del ***Laboratori Real 1 y 2*** promovidos por el CITIES (Centre Interdisciplinari de Tecnologia, Educació i Innovació per a la Sostenibilitat), la Universidad decidió promover la realización de Auditorías Energéticas en sus edificios siguiendo la metodología de análisis planteada, en el marco del Plan de Eficiencia Energética en el Consumo de Recursos (PECR) promovido desde la vicerrectoría adjunta de edificaciones.

El desarrollo de las auditorías se propuso como una línea de proyectos de fin de carrera, de la Escuela Politécnica Superior de la Edificación de Barcelona (EPSEB) y ha sido llevado a cabo en convocatorias anuales. Desde septiembre de 2003 a la fecha se han llevado a cabo 31 Auditorías de un total de 86 edificios de la UPC, las cuales se han realizado bajo la tutoría académica de las profesoras Montserrat Bosch e Inmaculada Rodríguez Cantalapiedra, y con mi apoyo como técnico del CITIES (Centre Interdisciplinari de Tecnologia, Educació i Innovació per a la Sostenibilitat).

Los resultados de esta experiencia docente se resumen en el artículo presentado al JOURNAL OF CLEANER PRODUCTION de la Editorial ELSEVIER, el cual ha sido aceptado para publicación en el próximo número de la revista que se incluye a continuación.



Involvement of final architecture diploma projects in the analysis of the UPC buildings energy performance as a way of teaching practical sustainability

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Received 1 August 2005; accepted 1 November 2005

Abstract

Education is the foundation for achieving sustainable development. With the purpose of facing sustainable challenges in terms of climate change, water and energy consumption, Technical University of Catalonia (UPC) has promoted the culture of energy efficiency in new generations of professionals that will work in the field of building construction. A group of 21 students taking the final official Diploma in Architecture were involved in a project of analysis of energy performance of UPC buildings in order to identify and implement cost-effective ways of promoting a greater environmental responsibility. The development of works focused the attention on introducing energy audits in existing university buildings, analysing the following aspects: surveying construction drawings, building characteristics, energy consumption, use of natural lighting, energy-saving lighting controls, water consumption, and high-efficiency HVAC systems. The ultimate goal was to draft a proposal for greater respect for the environment, and for corrective measures aimed at reducing the environmental impacts.

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Keywords: Curriculum greening; Energy efficiency; Interdisciplinary

1. Introduction

Sustainable development is an increasingly relevant goal in today's society, which should involve considerable change in our behaviours. A sustainable society can only be constructed through example, and through specific activities. The European Union (EU) Directive of building energy performance of buildings [1] could play a very important role in the future increase in energy efficiency. In many countries, current building codes have relatively low requirements for energy efficiency and renewable energy, which leads to a higher energy consumption than what is cost-effective. Because most houses

are built according to these low standards, the users are burdened with unnecessarily high operational costs. New, stronger building codes that are enforced, can correct this problem, to the benefit of the users, the constructors and the environment. The new professionals in building construction need to know what are the today's European standards requirements for energy efficiency and how to evaluate and modify the actual park of buildings.

Energy rating started just after the energy crisis. The concern of the industrialized countries about the high energy consumption of the building sector initiated actions and programmes aiming to rationalize the energy consumption of dwellings.

- In Denmark, energy rating schemes have been prepared for large commercial buildings since 1992. The scheme is mandatory, relatively costly and quite comprehensive.

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URL: <http://dfa.upc.es/websfa/eupb/inma.htm>

- In the UK, in the 1980s and 1990s performed hundreds of multi-year energy audits. They labelled buildings with different schemes.
- In Ireland, from 1992 labelled almost 8000 houses per year.
- In Spain, and in particular in the Basque Country, an energy rating system has been developed. Energy-efficiency certificates are awarded to buildings in two stages. A first certificate is awarded in the design phase and a final one is provided to the finished building.
- In the Netherlands, a rating scheme was developed in the mid-1990s.

The main purpose of this work is the analysis of the energy performance of UPC buildings in order to identify and implement cost-effective ways of promoting a greater environmental responsibility. The work is part of the framework of UPC policies [2] that, in 2003, launched a project for auditing the energy efficiency of the university buildings so as to establish a Resources Consumption Efficiency Plan (focussed mainly on energy and water).

The Technical Architecture School has adopted as a teaching strategy the principle that environmental issues should be dealt with throughout the whole course of studies as a part of the curriculum and in all subjects.

All students are required to complete a Final Project (PFC) at the end of their degree programme, providing them with an opportunity to specialise their studies and focus on the areas that interest them the most and in which they would prefer to undertake their professional careers.

UPC's interest in developing an Energy Efficiency Plan for consumption of energy resources, with the aim of auditing the existing buildings and defining policy and objectives for energy savings and efficiency, was seen as an opportunity for establishing links between teaching, research and management of the university. Within this framework, the Environment Plan Office, with the collaboration of the Department of Architectural Technology II and the Department of Applied Physics, has created a line of projects with the name Resources Consumption Efficiency Plan (PECR) – Energy Audits as a strategy focussing on learning by students.

The PECR has developed a practical and useful methodology for auditing the energy performance of UPC buildings and assessing their environmental quality. This goal has been pursued on the basis of yearly rounds involving groups of students who receive, over a six-month period, individual and group teaching that obliges them to do research and learn under the interdisciplinary guidance of a group of lecturers with specific knowledge.

The paper has the objective of publicising the results, from an academic standpoint, of a specific action carried out within the framework of the Energy Efficiency Plan (UPC, 2002) that is now being implemented and that will allow the existing commitment to greening the university studies in Technical Architecture School, to be strengthened. In the first stage, this task was performed through the energy audit of buildings and in particular of UPC buildings, and, in

view of the good results obtained, the second stage has now been started.

This action had the following goals:

- Address the need for curriculum greening;
- Develop a learning strategy;
- Create tools and a framework for work;
- Integrate different areas of work at UPC (teaching, research and management).

By means of Strategic Plans, our University has been making a sustained effort for several years aimed at greening the areas of teaching, research and technology transfer with the professional sector. This approach is carried through with the express commitment by the different departments to promote ongoing enhancement of the activities that were undertaken to stimulate students.

The completion of a Final Thesis in the Technical Architecture Diploma programme provides a good opportunity to work with those concepts on the basis of a comprehensive view of all the aspects involved in the construction process: optimisation of energy resources, energy savings and improvements, and construction procedures and treatment of the outer surface of buildings, among others.

For this purpose, the “Guide to Greening Final Projects” [3] was drafted in 1998, classifying theses into four different types, depending on the degree of implication of environmental issues.

Projects linked to the PECR arose in connection with these purposes and with the proposal of the Environment Plan Office to carry out an energy audit of all UPC buildings to assess their energy performance and establish potential improvements, both in respect of energy efficiency and consumption of resources, and to allow reduction of their environmental impact.

2. Methodology

The development of the project planning for six months in duration, involved 21 students of the Technical Architecture School of Barcelona (EPSEB), three lecturers and various staff members from the Environmental and Maintenance Offices and other units. It included a weekly seminar day in order to discuss all the concepts that arose, and to share experiences. In conclusion, it was an enriching experience for the students.

Each student was expected to do her/his own work, but they were also encouraged to co-operate and share their experiences, with the objective of ensuring consistently high quality of all the work done.

Once the programme was established, students were provided with tools and physical surroundings for their work for adapting the different projects to the index or programme (Fig. 1) established in advance consisting of:

- Summary of general characteristics, with measurement data, a use specification sheet and architectural information on the envelope and structure and interiors;

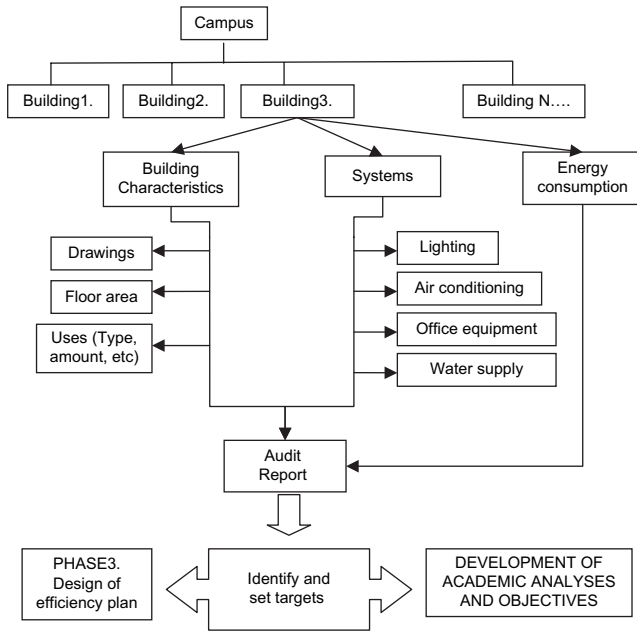


Fig. 1. Framework for performing the energy audits.

- Study of energy resources: electricity, gas, water, and other fuels;
- Analysis of systems of: lighting, air conditioning, energy and outfitting, and water pipes, providing plans and sets of data sheets compiling all the information;
- Monitoring of energy consumption;
- Data analysis and study of the energy efficiency of the building;
- Proposals for actions to be taken.

All data gathering, working methodology and analysis of the data obtained were carried out in accordance with models and experience provided by the tutors and experts consulted in the course of the work [4,5].

Lastly, summary sheets giving all the values obtained were drawn up for each building studied. In keeping with the standard reference parameters, the actions to be taken or the strategies to be applied with each building were determined, setting out the policies for energy saving and efficiency in accordance with the provisions of the UPC General Plan (Fig. 2).

3. Results and lessons learned

In order to evaluate the results of this initiative, a survey was carried out in which the students submitting their Final Theses were asked ten questions to assess the different aspects (cognitive, affective and methodological) that they encountered in the course of their work. A total of 16 questionnaires were evaluated.

In connection with cognitive aspects, the students stated that prior to completing this work their knowledge and aptitude in connection with environmental issues were not sufficient while after completing the project, they felt that both their knowledge and their aptitude for dealing with

environmental issues had improved to a satisfactory level. Consequently, more material on this subject should be included in the diploma programme in Technical Architecture and at the very least, the students have realised that there is more to be learned than what is available through academic training. Education continues outside the bounds of the prescribed studies.

Most of the surveyed students felt that both their sensitivity and their attitudes towards issues relating to the environment had changed satisfactorily and none of the surveyed students considered that their feelings on the subject had not changed sufficiently. We can therefore, state that they all felt that they had acquired certain new skills and attitudes. This is a very positive fact, since it indicated that carrying out a project relating to the environment had an influence on the formation of students' values, and this different outlook will undoubtedly lead them to work differently in their chosen professions.

Assessment of the new model of tutorial experience was positive, particularly regarding the regular meetings, which served to provide the information needed to the carry out the project and to allow the students themselves to create synergies and means of co-operation to deal with the problems that arose repeatedly, and to contrast working methodologies.

In the opinion of the lecturers, the web page was used effectively to transmit information that could be of use to all the students. It is important to bear in mind that working with 21 students at once and tutoring their theses involves a substantial amount of work. The fact that certain information, such as data tables, bibliographic selections, reviews of articles relating to the work, examples of construction elements taken as models, etc., can be provided in common to all the students makes the tutorial more efficient. We understand, nevertheless, that student's satisfaction might not be the same as ours, due probably to a different perception than in circumstances where more personalised attention is given, but we should point out that such attention was also provided in this case, at all times attempting to focus it on issues that will be more directly related to the final energy consumption of buildings and its associated environment impact.

4. Conclusions and recommendations

Completion of Final Projects provides students with an excellent opportunity to specialise their studies and focus on the areas that interest them the most and in which they would prefer to undertake their professional careers.

University energy audits are an opportunity for students to integrate and apply the knowledge they learned in the various fields of building construction during their training, in a real-life situation, and in a comprehensive manner.

The creation of workshops for preparation of Final Theses fosters interdisciplinarity, teamwork and the exchanges of experiences.

Lecturers benefit from the approach by having the opportunity to broaden their knowledge through exchanges and collaboration with colleagues in other disciplines. It is also

BUILDING INDICATORS-SUMMARY SHEET			
	Values	Reference values	Actions
Total surface	0 m2	-	
Total volume	0 m3	-	
BUILDING			
Normative			
Isolation			
Wall Transmission Coefficient	0,00W/m2°C	0,73W/m2°C	
Façade 1	0,00W/m2°C	-	
Façade 2	0,00W/m2°C	-	
Façade 3	0,00W/m2°C	-	
Façade---	0,00W/m2°C	-	
Window Transmission Coefficient	0,00W/m2°C	3,90W/m2°C	
Façade 1	0,00W/m2°C	-	
Façade 2	0,00W/m2°C	-	
Façade 3	0,00W/m2°C	-	
Façade 4	0,00W/m2°C	-	
Façade---	0,00W/m2°C	-	
% Total Windows	0,00%	-	
Cover Transmission Coef	0,00W/m2°C	0,41W/m2°C	
South solar protections	yes-no	Must have	
INSTALATIONS			
UPC values			
Thermal Conditioning			
Heating	yes-no	yes	
Tipus	collective / Individual	Colect	
Energetic source	Gas/ electr /other	Gas prefer	
Demand / consumption	Theoric Demand/consumption	0%	
Cooling	yes-no	yes	
Tipus	colectiv / Individual	Heat Bomb hight COP	
Energetic source	Gas/ electr /other	-	
Demand / consumption	Theoric Demand/consumption	0%	
Lighting			
Normative			
Ofices			
Tipus	Fluoresc /incandes /etc.	Low consum fluoresc	
Level	0 Lux	500 Lux	
Classroom / Laborat			
Tipus	Fluoresc /incandes /etc.	Low consum fluoresc	
Level	0 Lux	500 Lx	
Corridors / comunit			
Tipus	Fluoresc /incandes /etc.	Low consum fluoresc	
Level	0 Lux	100	
INDOOR AIR QUALITY			
UPC values			
Winter indoor T°	0 °C	20 °C	
Summer indoor T°	0 °C	25 °C	
Air renovation	0 m3/h pers	30-50 m3/h pers	
CONSUMPTION MESUREMENT			
UPC values			
Measurement systems			
Electricity	colectiv / Individual	Individ electronic	
Gas	colectiv / Individual	Individ electronic	
Water	colectiv / Individual	Individ electronic	
CONSUMPTION INDICATORS AND ASSOCIATED ENVIRONMENTAL IMPACTE			
	Value	Reference	Actions
CONSUMPTION			
UPC values			
Electricity	0 Kwh	XX kwh/any	
Gas	0 Kwh	XX kwh/any	
Water	0 m3	XX m3/any	
Indicators			
Consumption per m2	0 Kwh/m2	XX kwh-m2/any	
Consumption per crédit	0 Kwh/credit	XX kwh-cr/any	
Consumption per usuari	0 Kwh/per-any	XX kwh/any-pers	
ASSOCIATED IMPACT*			
Anual emission CO2	0 Tn/any	XX Kg-CO2 / m2	
Anual emission CO2	0 KgCO2/m2	XX Kg-CO2 / m2	
* 0.545 Kg/co2 per Kwh of electricity and 0,20 Kg/co2 per Kwh of gas.			Data de actualització

Fig. 2. Summary sheet.

true that tutoring groups of students demands substantial dedication and requires tutors to maintain very high standards for themselves.

In short, the completion of these Final Theses has addressed a need in connection with curriculum greening through development of a learning strategy and creation of the suitable tools and operational framework.

Sustainable development and respect for the environment are a major challenge that society must deal with. Experts in construction will play a key role in contributing to the technological development that society needs, and the university must train professionals to lead this process of change.

The educational background of the students regarding the environment and sustainability is very important in this

process, particularly in that they gain the capacity to analyse the information and to define the objectives. If this input is limited, the process will be hindered and the activities delayed, as time must be devoted to providing this background.

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